DEDICATED FIXTURE DESIGN FOR POLISHING OF SILICON

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurrently submitted for award of other degree.

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To beloved Mom and Dad, the love of my life

“Vision without action is day dream and action without vision is a nightmare”

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ABSTRACT

Polishing of silicon is a major process seen in microelectronic and optical industries. As mirror-like surface finish is an essential factor that influences the performance of electronic and optical products, it has been believed that the fixture in finite element does play a role to produce such a quality surface on silicon. This paper centers on designing the fixture in finite element environment for polishing of silicon. Polishing process was virtually developed using general purpose FE codes. Process model consist of major components needed for polishing such as the base plate, the pad, the abrasive, silicon and of course of fixture. Currently only 2D model was considered because of the complexity of the process and limitation of the FE code. Fixed diamond abrasive proposed by VTT microelectronics was created in FE model to overcome the modeling difficulty of loose abrasives, to conveniently define polishing forces involved, and also investigated the effectiveness of the new abrasive design. Polishing forces were split into two-normal and tangential forces. The presence of micron-size diamond abrasive was modeled by defining friction coefficient at the interface between silicon and abrasive sheet. Typical values of polishing forces were defined as recommended by manufacturer. Finer mesh was designed at the top layer of the silicon in order to simulate the action of the diamond abrasive realistically. Polishing process was simulated by changing the various fixture designs. The goodness of the fixture design was justified by absence of high stress concentration in anywhere in the silicon.

ABSTRAK

Proses menggilap silikon adalah proses yang sangat penting didalam industri mikro-elektronik dan optik.Faktor penting yang mempengaruhi keberkesanan mikro-elekronik dan optik produk adalah ialah pemukaannya yang seperti cermin, maka dipercayai bahawa pemengang khas memainkan peranan penting dalam proses menggilap silikon.Tesis ini menfokuskan penciptaan pemengang silikon dalam kaedah "finite element". didalam proses menggilap. Proses menggilap dilakukan secara tidak nyata melalui kod umum FE. Bahagian utama didalam proses adalah seperti plat dasar, pelapik kesat, silikon dan yang terutama sekali adalah pemengang khas. Kini hanya model dua dimensi yang di pertimbangkan memandangkan kod khas didalam "finite element" adalah terhad dan sangat rumit. Pelapik belian kasar jenis tetap yang di cadangkan oleh VTT mikro-elekronik telah dimodelkan untuk mengatasi kesukaran pelapik kesat jenis tidak tetap. Untuk memudahkan kerja, daya penggilap ditentukan dan keberkesanan penciptaan pelapik kesat yang baru turut dikaji. Daya penggilap terbahagi kepada dua jenis iaitu daya" normal and tangential". Untuk menunjukan berlian kesat yang bersaiz mikro, ianya dimodelkan dengan pekali geseran pada permukaan diantara silikon dan pelapik kesat. Daya-daya penggilap sebenarnya ditentukan berdasarkan cadangan oleh industri. Untuk menunjukan kesan simulasi menggilap yang nyata "mesh" yang halus di lakukan pada bahagian atas silikon. Keberkesanan pemengang khas adalah ditentukan berdasarkan kehadiran tekanan daya yang kuat dan menumpu pada mana-mana bahagian silikon.

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$\boldsymbol{\sigma}_{\mathbf{z}}$	-	Stress of z-axis
$\boldsymbol{\tau}_{\mathbf{xy}}$	-	Shear stress of x and y axis
$\boldsymbol{\tau}_{\mathbf{xz}}$	-	Shear stress of x and z
E	-	Modulus of Elasticity
FE	-	Finite Element
FEM	-	Finite Element Method
FEA	-	Finite Element Analysis

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Silicon has been sought for 90% application in optical and electronic industries. It has played a major role in infrared application, integrated circuit technology and Microelectro-mechanical systems (MEMS) components. Performance of the component rely on the surface integrity, where polishing is an essential. However characteristic of silicon is very often make polishing process difficult. One of these is its brittleness. In order to obtain a surface with mirror finish and perfect form, fixture design is one of the influencing factors

Fixture can be classified as dedicated or reconfigurable. Dedicated fixture generally implies that they have been designed for specific workpiece geometry. Therefore dedicated fixtures are specially designed and fabricated for a given workpiece and are used in mass production due to the advantages of specially designed performance, such as convenient operation, stiff support in desired directions, and efficient structural space utilization.

Since fixture design contributes significantly to the manufacturing quality and lead time, it is desired to automatically design and verify dedicated fixture in the product design and manufacturing planning stage so that alternative designs can be compared for optimal solutions.

Fixture design research using computer aided design started early 1980s. Computer-aided fixture design (CAFD) techniques have been advanced rapidly so that fixture configurations can be generated automatically. Interactive fixture design techniques were built up on top of commercial computer aided design system and expert system tools.

However the approach were mainly concerned with fixture configuration and there are little analysis. Comprehensive fixture design should have analysis at different computational level. In this aspect, finite element modeling and analysis can be a good choice.

1.2 PROBLEM STATEMENT

In the optical and electronic industry surface integrity is a major quality- related problem. polishing of silicon is essential process, where dedicated fixture play important role to produce a component of high quality finish, however the important design concept seem to be overlooked and often design is based on try and error. Brittle nature of silicon is problematic in polishing.

1.3 OBJECTIVE OF THE PROJECT

I. To develop virtual process polishing using finite element method.
II. To design a fixture based on the analysis at different computational level.
III. To obtain database for feasible fixture design of polishing process.

1.4 SCOPES

I. The fixture used in typical polishing machine will be designed.
II. General purpose finite element code (ALGOR) will be used to design and analysis feasibility of fixture design based on stress theory.
III. Simulation of polishing process will be carried for various fixture geometries and material
IV. Design feasibility will be based on theories of plasticity and fracture mechanics

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Fixtures are important in both traditional manufacturing and modern flexible manufacturing system (FMS), which directly affect machining quality, productivity and cost of products. The time spent on designing and fabrication fixtures significally contributes to the production cycle in improving current product and developing new products.

Therefore, great attention has been paid to study of fixturing in manufacturing (Thomas and Ghadhi, 1986). A fixture design used in machining, assembly, welding and other manufacturing operation to locate and hold a work piece firmly in position so that the required manufacturing process can be carried out corresponding to design specifications (Nee and Senthil kumar,1991).

2.2 FIXTURE

Fixtures were develop for job, batch and mass productions, which are widely used in manufacturing operations locate and hold a part firmly in position so that the required manufacturing process can be carried out according to design specifications (Hoftman,1991)

In machining processes geometry accuracy of manufactured part mainly depend on the relative position of workpiece (silicon chip) to the machining tool (Rong, 1988).Fixture are needed to locate the workpiece relative to the machining tool in order to ensure the manufacturing quality. It is clear that the primarily requirement s for a fixture are located and secured the workpiece in a given position and orientation on a worktable of a machining tool.

To secure the workpiece on a fixture, clamps are often utilized to keep a stable location against the machining force. Clamping method can be classified into top and side clamping, which may provide normal and friction force, but in this case polishing due on top surfaces and top clamping is not encouraged. The fixture must be rigid enough to resist the harmful deformation and vibrating during machining. Clamping method and clamping position should be carefully selected to firmly hold the workpice .

In addition to the primary requirements in fixture design, many other demands also found, such as ensuring productivity like easy load and unload of the workpiece, utilization of automated or clamping semi automated devices. Special design for reducing formation of weak rigidly parts, simple and safe operation and effective cost reduction.

Hence the fixture design is complicated process. The application of these fundamental principles to individual fixture design depends on primarily designer's experience in manual fixture design.

2.3 DEDICATED FIXTURES

Since dedicated fixtures are commonly used in mass production, dedicated fixtures design are usually applied the fixture construction is perfectly designed for specific operation. As part of machining tooling, the application of dedicated fixture has greatly contributed to the development of automated manufacturing system. Therefore dedicated fixture designs are specially designed for each specific operation, with special consideration of fixture structure, auxiliary support, and other operational properties.

Moreover, the operations can be conducted quickly and the tolerance requirement can easily assured in the operation. The problem involving in dedicated fixture application includes the flexibility and long lead time required to designed and fabricate the fixture. When product design change like the shape and the size changes he dedicated fixture are usually not longer useful and scrapped. Today a flexible fixture is desired to a certain extent in order to design variations of the products.

2.4 FIXTURE DESIGN PRINCIPLE

Fixtures are one of operational equipment in manufacturing which are used to ensure the product quality and operational efficiency. Fixture design is desired to be rapid or on time, effective and economic.

2.5 POLISHING PROCESS

Polishing is the removal of material to produce a scratch-free, specular surface using fine (<3 μm) abrasive particles. Polishing is typically done at very low speeds using either polishing cloths, abrasive films, or specially designed lapping plates. Polishing with a cloth or lapping plate requires the use of free abrasive, and is a very low damage process when performed properly. Plate material and cloth material are critical when polishing a particular sample as the properties of these substrates are important in the final polish quality of the specimen.

2.5.1 Lapping

Lapping is the removal of material to produce a smooth, flat, unpolished surface. Lapping processes are used to produce dimensionally accurate specimens to high tolerances generally less than 2.5 μm uniformity. The lapping plate will rotate at a low speed (<80 rpm) and a mid-range abrasive particle (5-20μm) is typically used.
Lapping removes subsurface damage caused by sawing or grinding and produces the required thickness and flatness. Although the lapping process is less damaging than grinding, there are two regimes of lapping free abrasive lapping and fixed abrasive lapping.

Free Abrasive Lapping is when abrasive slurry is applied directly to a lapping plate e.g. cast iron. This is perhaps the most accurate method for producing specimens and causes the least amount of damage. Free abrasive lapping is accurate because of the rigid lapping surface which can be tailored to suit a particular material. Fixed Abrasive Lapping is when an abrasive particle in bonded to a substrate as with abrasive lapping films and SiC papers.

Abrasive lapping films have various particles bonded to a thin, uniform polyester substrate and are also capable of producing a very flat surface. SiC papers are much thicker than the film and create the potential for rounded edges on the sample.

2.6 POLISHING MACHINE

Lapping and polishing machines vary extensively depending upon the manufacturer. SBT (South Bay Technology) has designed a set of instruments that are specifically designed for universal lapping and polishing applications. Although variety of polishing machines is available nowadays polishing mechanism is basically the same

2.6.1 Model 920

The Model 920 Lapping and Polishing Machine (Figure 2.1) incorporates a precision spindle assembly housed in a solid cast aluminum casting to provide stable operation in any laboratory environment. Stability when lapping is critical in producing flat precisely controlled tolerances on a given specimen. The motor is a high torque, variable speed motor that allows a wide range of speeds to be employed.

Flexibility in speed control allows the instrument to be used as a grinding machine, high quality lapping machine, or polishing machine. During grinding high speeds are required, whereas lapping and polishing applications are generally completed at low speeds. The Model 920 also incorporates workstations, which allow for the use of precise Lapping and Polishing Fixtures.

Figure 2.1: Model 920 Lapping and Polishing Machine for precise lapping and polishing applications

2.6.2 Model CL50

The CL50 Lapping Machine (Figure 2.2) is a robust machine evolved specifically to meet the requirements of the low volume producer of thin sections. Its compactness makes the most of valuable laboratory space and the resilient plastic casing is easily cleaned. For convenience, the lapping plate is of a lift-off design which allows both quick and simple plate changing and easy access to the base of the machine for cleaning

A water flush nozzle is also provided to assist with this. The Abrasive Auto feed System does away with cumbersome manual techniques of applying abrasive and ensures a reliable volume and consistency of abrasive to lapping plates at all times. This means that processes can be repeated accurately